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ESNII
European Sustainable Nuclear Industrial Initiative : Generation IV Demonstration Fast Reactors

Noel Camarcat
chair ESNII Task Force
FISA 2019 Conference Pitesti, Romania 5 june 2019

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ESNII: the actors

- The **ESNII Task Force**
  - *Memorandum of Understanding* under SNETP umbrella
  - 13 founders in 2010, now 31 members : latest comer PSI from Switzerland joined on 7 july 2017
  - Industry : 12 members, research organisations : 19 members

Industry | **Research**

- For manageability, the ESNII Task Force decided to set up a 2-level structure:
  - Task Force: all members
  - Coordination Committee : leaders of the ESNII projects

ESNII Scope (3 Gen IV technologies, 4 projects)

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- ESNII is an Instrument for coordinating the implementation of the SNETP pillar on **sustainability of nuclear fission, based on Gen IV fast reactors with closed fuel cycle.**
- 3 main technologies are studied in Europe with the objective to reach the demonstrator stage : Lead-Bismuth and pure Lead, Sodium (SFR), Gas (GFR)
- ESNII Projects and System maturity have evolved in the last 10 years:
  - From 2010 to 2018 : Sodium SFR's were the leading technology and demonstration project in Europe
  - Early 2019 : announcement by the French government that sodium demonstration projects are no longer needed for the short and medium term as industrial perspectives for sodium reactors are postponed. The new French strategy for closing the fuel cycle has been detailed by P. Stohr the CEA Director at the recent ICAPP conference (may 2019)
  - The Myrrha demonstrator (SCK-CEN) is now the leading generation IV project in Europe. It uses lead-bismuth as coolant.
  - Pure lead, Sodium and Gas technologies are also studied in Europe. Their demonstrator stage is not as advanced as MYRRHA

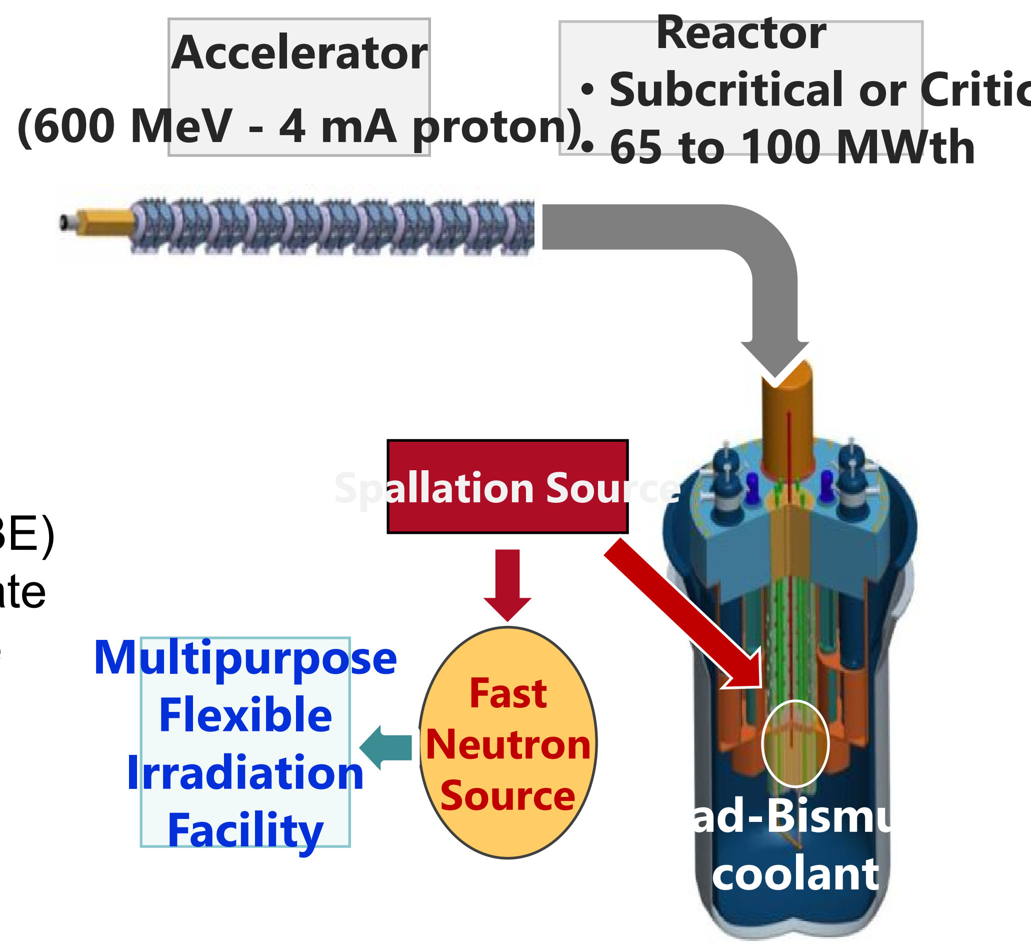
MYRRHA

Construction of an Accelerator-Driven System (ADS) consisting of

A 600 MeV –
2,5 to 4,0 mA proton linear accelerator

A spallation target/source

A lead-Bismuth Eutectic (LBE) cooled reactor able to operate in subcritical & critical mode



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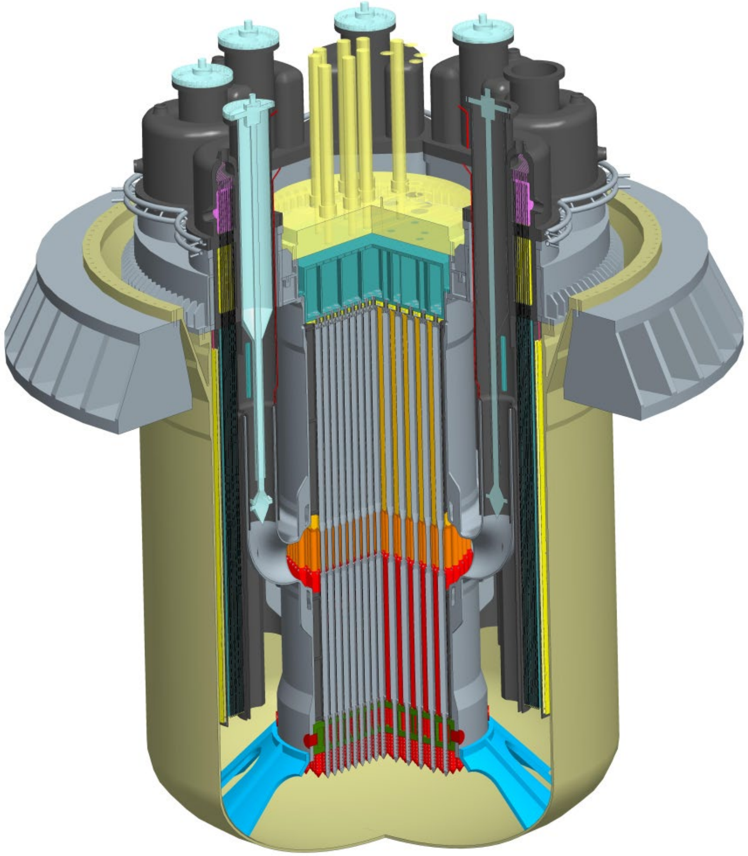
ALFRED (pure) Lead Technology

To provide Europe with:

- a **Demonstrator** devoted to the **Development** of the **LFR** technology
- a **Reactor** addressing the concerns on **Safety** and **Sustainability** of **Nuclear Energy**
- a **Research Infrastructure** to build and maintain the **European Leadership** on scientific excellence



Lead Fast Reactor -120 MWe

The ALFRED Project in a nutshell

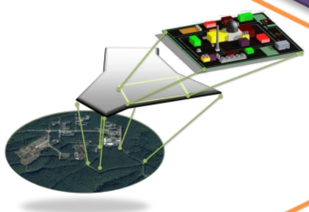
Who?

ALFRED Construction is fostered by the FALCON Consortium (Ansaldo Nucleare, ENEA and Romanian R&D Institute ICN)

Why?

ALFRED has strategic and socio-economic relevance at EU, National and local level

Where?



Mioveni nuclear platform in Romania is the candidate site for ALFRED

When?

ALFRED construction is foreseen to be completed by 2030

How?

ALFRED will be supported through a distributed Research Infrastructure covering 9 scientific objectives

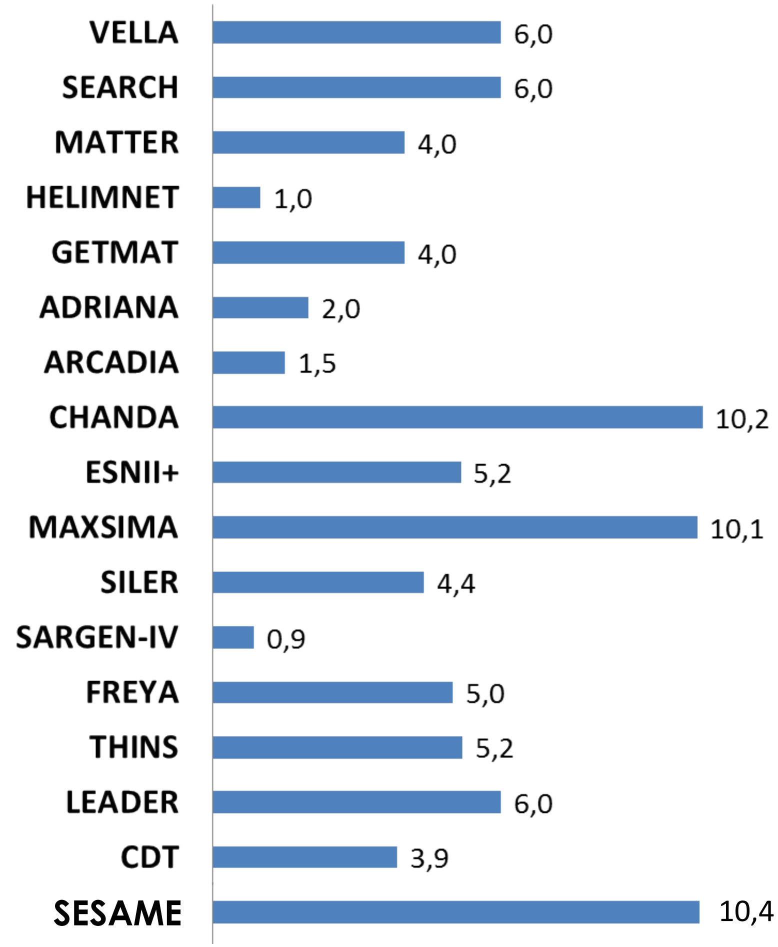
ALFRED Project:
EU support

EURATOM FP5, FP6, FP7

- more than **25 R&D indirect** actions and **10 R&D direct** actions (on LFR)
- about **90 M€** between direct and indirect actions (45 M€ in-kind)

Through FALCON:

- **3 full-members + MoAs** with associated partners
- Membership and associated partners support based on **in-kind contributions**



Ref: *Euratom Contribution to the Generation IV International Forum Systems in the period 2005-2014 and future outlook*, EUR 28391 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-349328-7, doi:10.2760/256957, JRC104056

ALFRED Project: the Romanian support

2014: Government memorandum for the **construction of ALFRED in Romania**

2015: ALFRED included in **Smart Specialization Strategy** of South-Muntenia

2017: ALFRED included in National strategy and Plan for RDI 2015-2020 as a **European project of national interest**

2017: ALFRED in the **National Research Infrastructure Roadmap**

2018: ALFRED **in National Energy and Climate Plans (NECPs); draft submitted to EC**

funds		
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Short term availability	R&D[2] RDI Project[3] Minor Project[4]	7,5 M€ up to 2 M€ 20 M€
Planned for the future	Facilities ALFRED	45 M€ 200 M€

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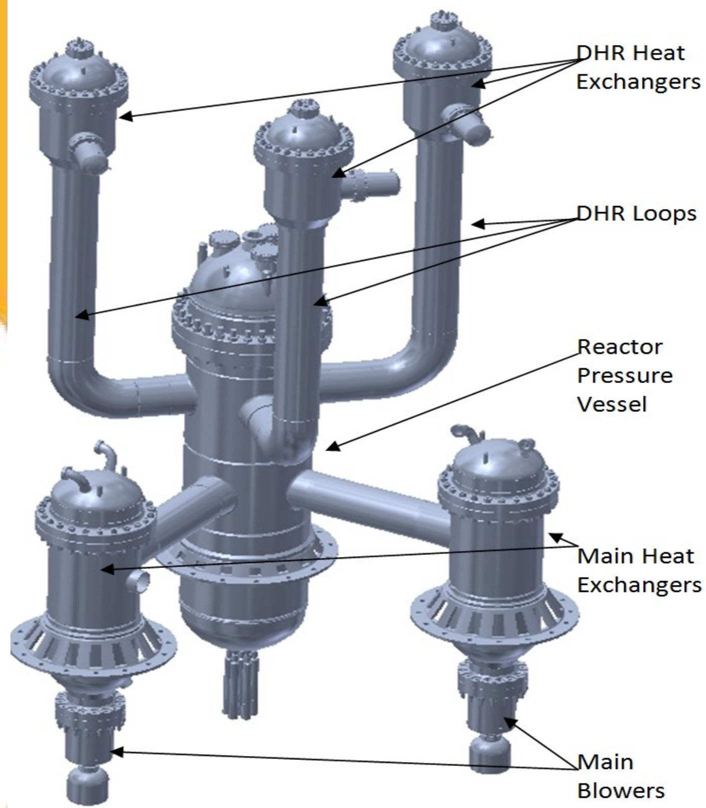
[4] Waiting for award

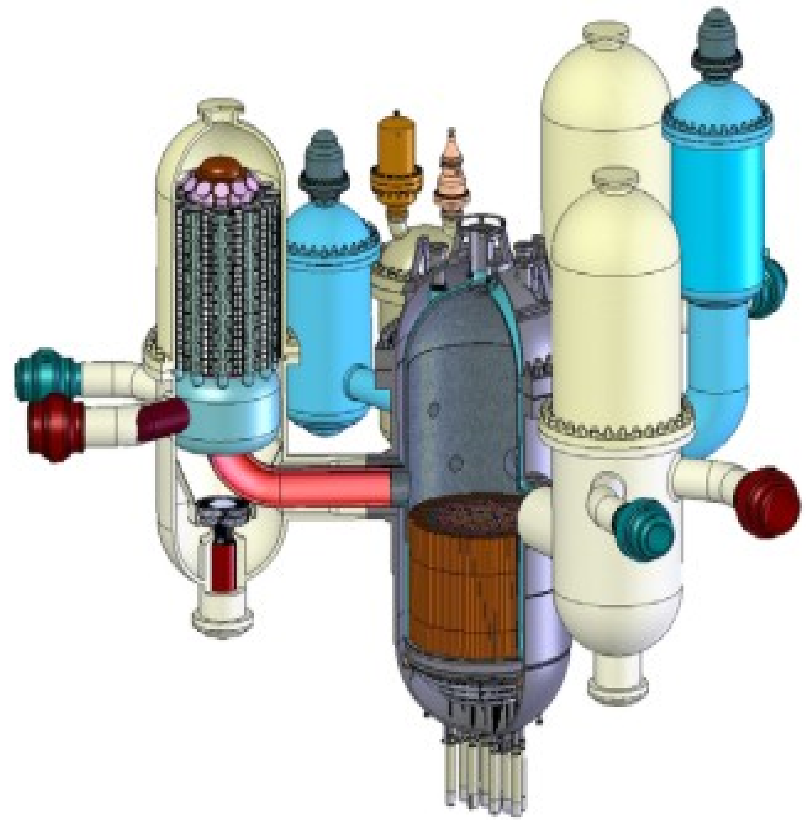
2018: Call for support Infrastructure projects: proposal submitted as World relevant experimental facilities at Mioveni site (**20 M€**)

2019: RDI project for Generation IV reactor ALFRED (**2 M€** expected in 2 years)

ALLEGRO Project : Gas Fast Reactor (GFR)

Allegro design : 75 MWth demonstrator

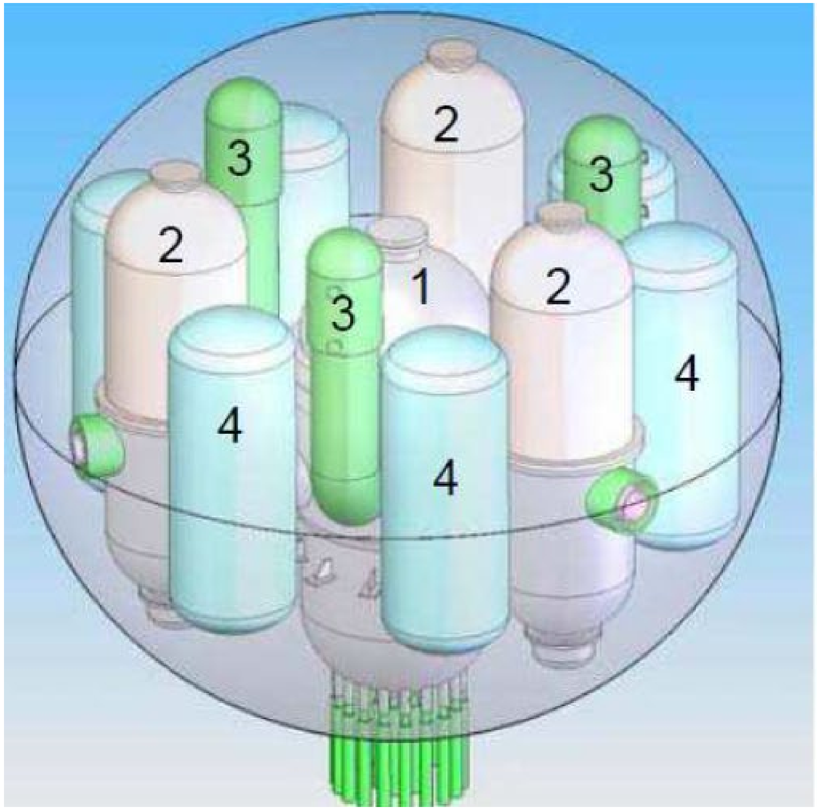




Full scale 2400 MWth Reactor

Gas Fast Reactor Technology

(B. Hattala, Vüje Esnii april 2018)



The whole primary system is enclosed in a small pressure guard containment.

1 - vessel

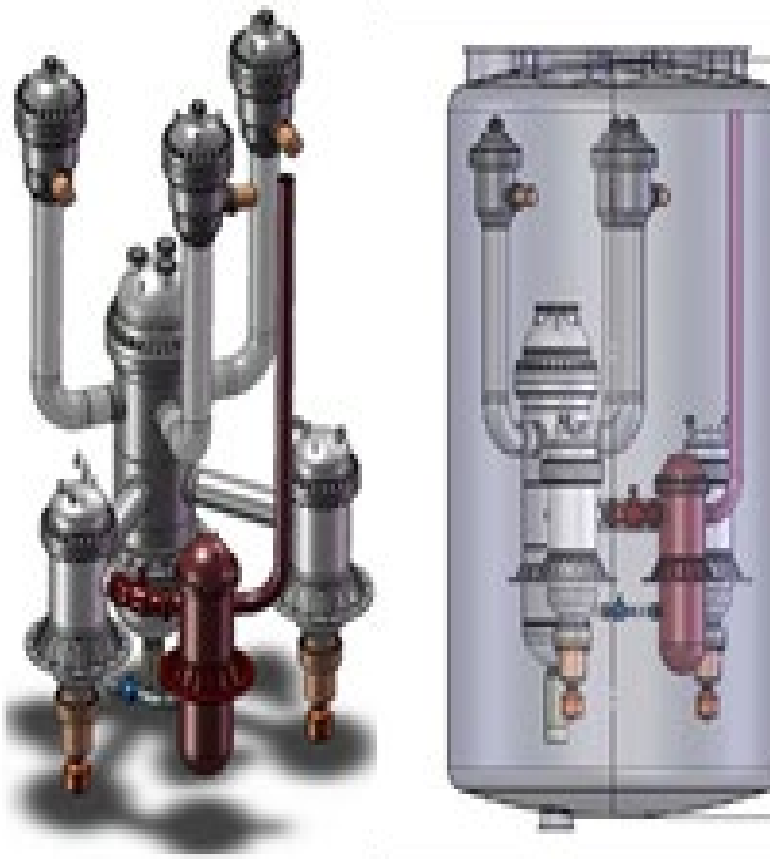
2 - three Main Heat Exchangers

3 - three Decay Heat Removal loops

4 - six gas reservoirs

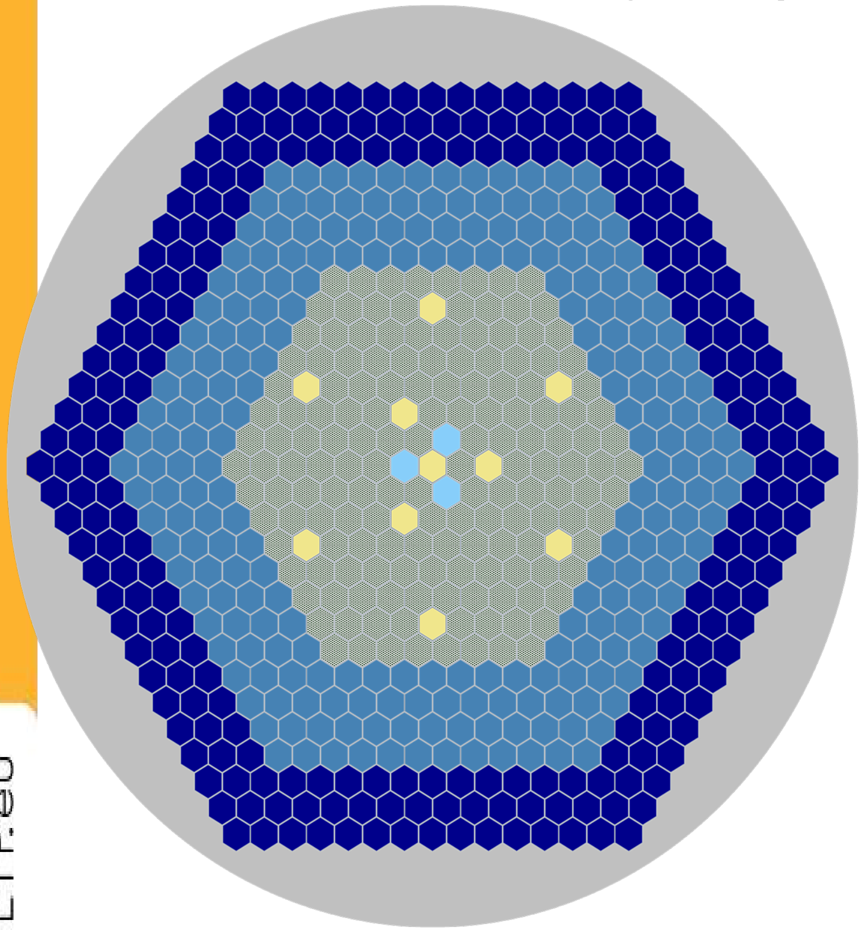
ALLEGRO

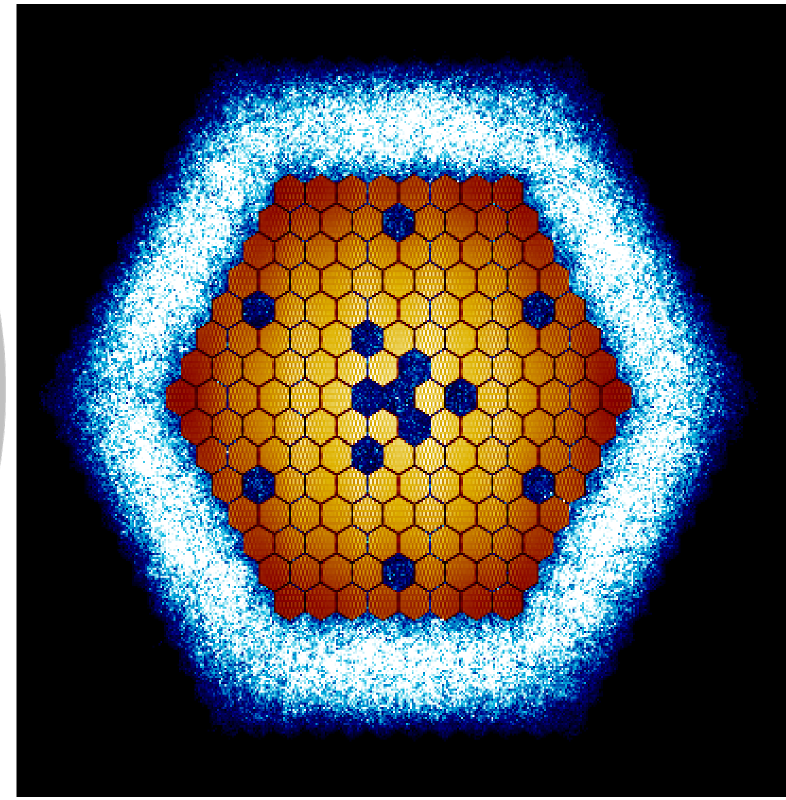
- New Strategy announced by the 4 partners V4G4 in central Europe in early 2015
- Reduce ALLEGRO power from 75 MWth and optimize the core configuration
- To increase main blowers inertia (Management of LOCA and SBO), gas turbine coupled to the primary blowers
- UO2 pellet or MOX Pellet in AIM1 Stainless Steel cladding and develop in phase 2 a ceramic design



UOX ALLEGRO

UOX core analysis (VUJE, SERPENT)





UOX Core, 2 rings more + axial enlarge, 3 exp. positions only, 75 MW_{th} and 37.5 $MW_{th.}$

With UOX core, 560°C outlet temperature. With Ceramic (U,Pu)C – SiC fuel, outlet temperature can reach 850°C

FRENCH STRATEGIC INDUSTRIAL AND R&D ROADMAP FOR CLOSURE OF THE FUEL CYCLE

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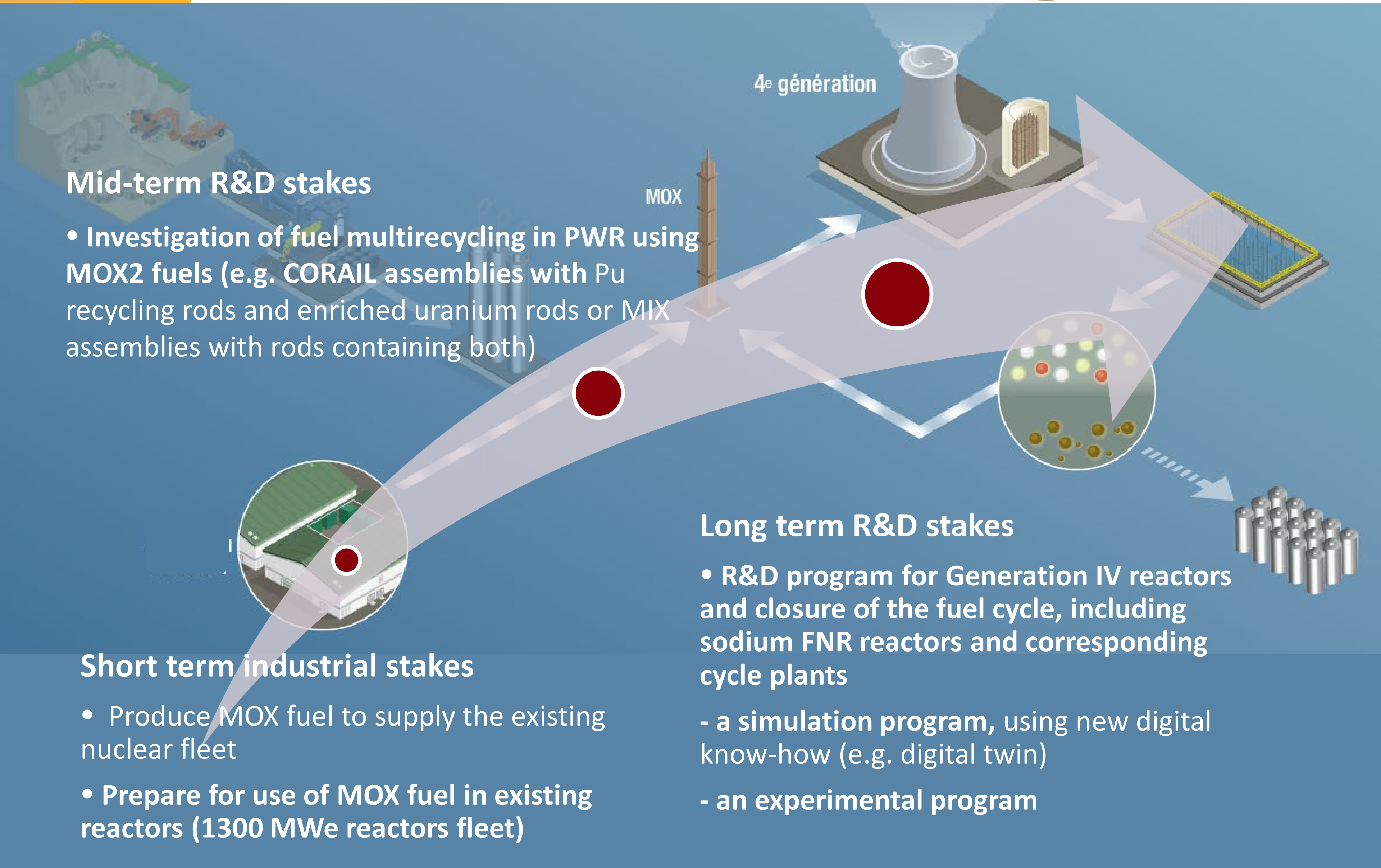

Mid-term R&D stakes

• **Investigation of fuel multirecycling in PWR using MOX2 fuels (e.g. CORAIL assemblies with** Pu recycling rods and enriched uranium rods or MIX assemblies with rods containing both)

Short term industrial stakes

• Produce MOX fuel to supply the existing nuclear fleet

• **Prepare for use of MOX fuel in existing reactors (1300 MWe reactors fleet)**

Long term R&D stakes

• **R&D program for Generation IV reactors and closure of the fuel cycle, including sodium FNR reactors and corresponding cycle plants**

- **a simulation program,** using new digital know-how (e.g. digital twin)

- **an experimental program**

R&D perspectives to investigate Multi-recycling in PWR's

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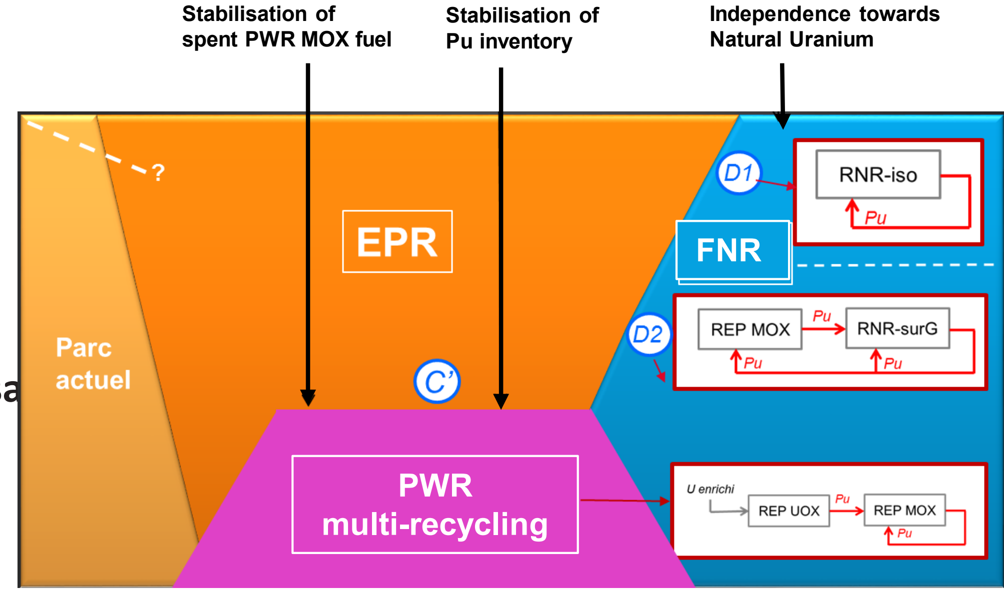
Multi-recycling in PWR's research program

- R&D program under development by CEA and industrial players (EdF, Framatome and ORANO)
- Global vision of a possible industrial cycle to be constructed
- Potential industrial deployment of multi-recycling in PWR to be assessed through scenario studies (continuum from mono-cycling to complete fuel cycling with FNR)

Scientific and technical challenges to be addressed

- Neutronics and core design
- Adaptation of PWR reactors
- Radioprotection
- Adaptation of fuel cycle plants (La Hague and Mélox)
- Impacts on deep geological disposa



R&D perspectives for advanced reactors

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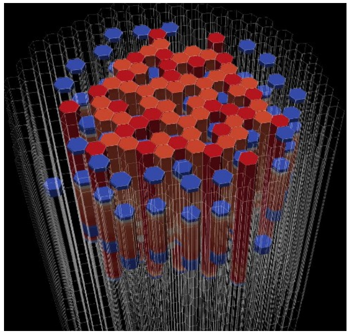
Gen-IV reactors and cycle : focusing on SFR while assessing other FNR concepts

- Consolidation of technical knowledge on sodium FNRs and further R&D development of 4th advanced generation technologies
  - Development of SFR concept and qualification of industrial components
  - Sketch studies and R&D assessment of other FNR technologies
- Fuel reprocessing: advanced processes and technologies for recycling
  - MOX manufacturing for FNR
  - Multi-recycling process for U and Pu (CORAIL/MIX)
  - Assessment of multi-recycling
    (on Pu flow and Minor Actinides inventory to deep geological disposal)



SMR : a new paradigm for nuclear plants and for the energy system ?

- **Modular design and realization** with pre-manufacturing in industrial facilities for minimizing on-site construction and optimizing costs.
- **Access to nuclear power**, e.g. for countries with limited needs (networks, additional power capacity or financial constraints)
- **Flexibility** in an energy mix with renewable energy production
- **Non electronuclear and hybrid concepts**
  (heat production, hydrogen production, storage and system coupling ...)

Results of ESNII and orientations for the future (1/2)

- ESNII promotes 4 main projects and technologies but does not distribute money
- Its important accomplishments are evaluation of projects and systems maturity, coordination of research and of European research teams and technical advice to emerging projects
- In the technical field it has achieved some harmonisation of fast reactor fuel R&D in Europe. Other Generation IV Fora and comunities are more diverse : in Asia (3 fuels), in Russia (3 fuels), GIF treats all types of fuels
- For the next 20-25 years, Europe through ESNII will use one R&D fuel for its leading projects : **mixed uranium and plutonium oxide, (pelletized) MOX** with an offshoot for Allegro phase 1 and phase 2.
- This important technical choice must be consolidated in the detailed research programs and projected in the future for the next 10 years.

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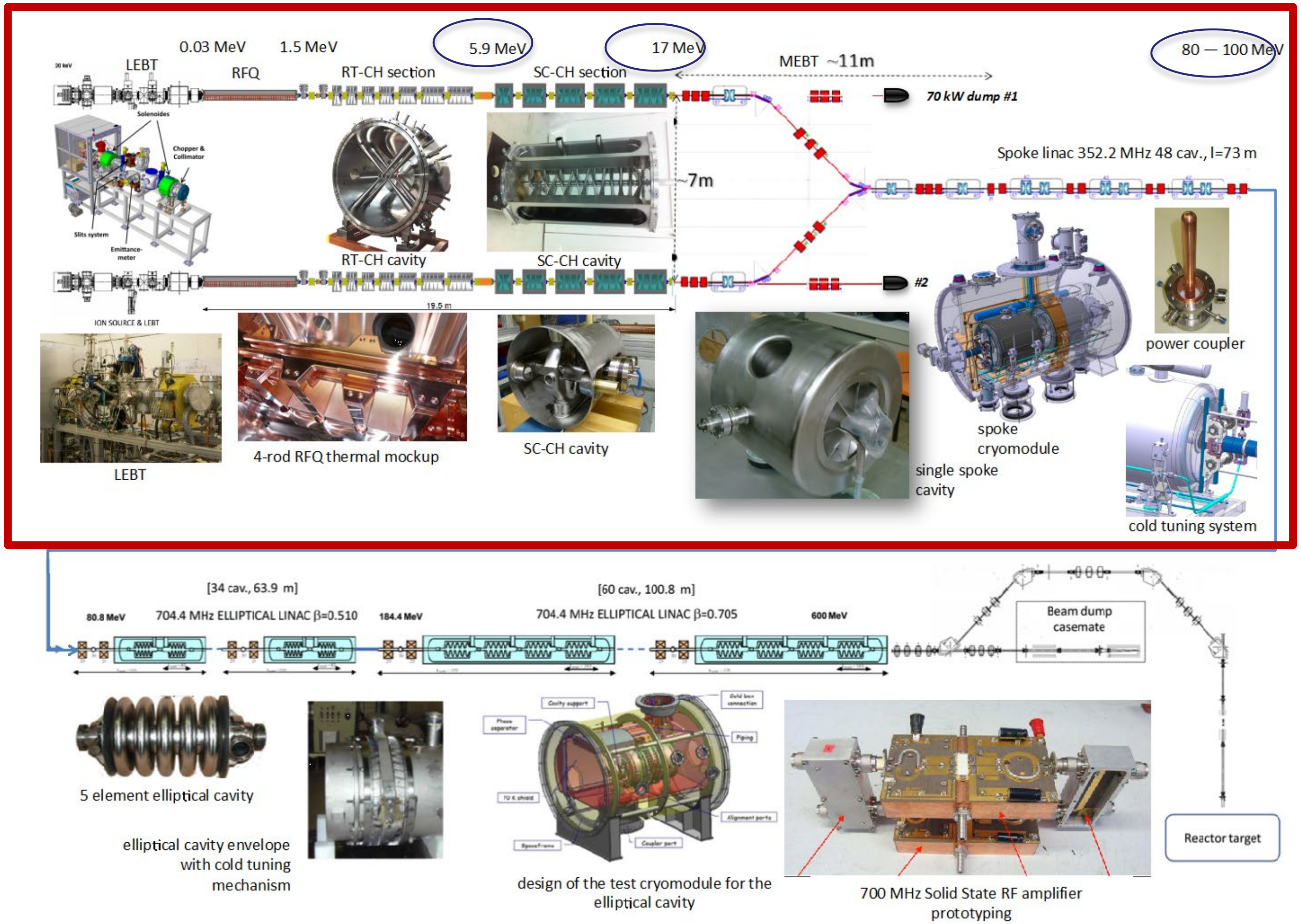
Results of ESNII and orientations for the future (2/2)

- For the 2019-2023 Euratom R&D program, MOX Fuel research is funded through the INSPYRE and ESFR SMART projects with EC money and Member States money. Some Member States and **industrial partners are also funding Fast Spectrum MOX fuel research at a higher level**
- MYRRHA has moved ahead significantly and is now the **first European Fast Spectrum** demonstrator project in the ESNII community
- Worldwide, Sodium technology is becoming industrial (5,57 TWh produced in 2017 by BN800, Russia). Large power reactors will remain the mainstream of the technology, but other ideas can emerge in Europe (Sodium SMR's,…….)
- Allegro and ALFRED are particular since they have access to european structural funds
- But the 4 projects will need public support and acceptance from the research community at large. They **will need long term research** in parallel with project basic and detailed design. Construction will depend on funding

Thank you for your attention

Accelerator Project

MYRRHA accelerator 0 – 100 MeV section



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MYRRHA - Belgian Government decision on September 7, 2018

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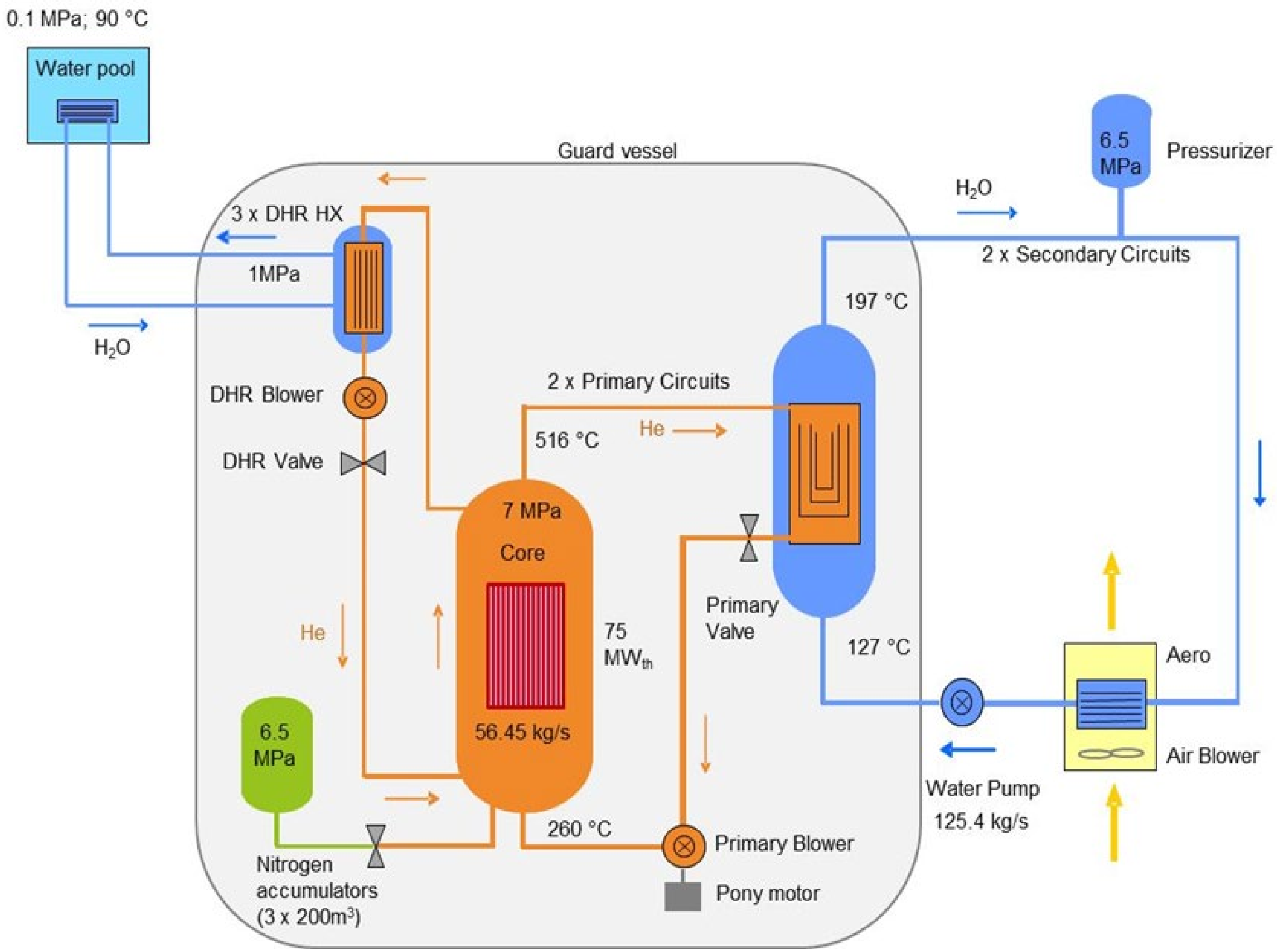
- Belgium allocated 558 M€ for the periode 2019 – 2038:
- 287 MEUR investment (CapEx) for building MINERVA (Accelerator up 100 MeV + PTF) for 2019 - 2026
- 115 MEUR for further design, R&D and Licensing for phases 2 (accelerator up to 600 MeV) & 3 (reactor) for 2019-2026.
- 156 MEUR for OpEx of MINERVA for the periode 2027-2038
- Belgium requests to establish an International non-profit organization (AISBL/IVZW) in charge of the MYRRHA facility for welcoming the international partners
- Belgium continues to mandate Secretary of State for Foreign Trade Mr Pieter De Crem for promoting MYRRHA and negotiating international partnerships

Allegro Thermal Hydraulic Benchmark (ESNII Task Force 07/07/2017)



Courtesy of B. Hattala, Vüje, Slovakia

ALLEGRO R&D: Helium loops
(SK and CZ at Esnii task force 23/01/18)

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- **The R&D in V4G4 has so far focused onto two helium loops:**

- **STU loop (Trnava, SK): Natural circulation**
  - 1 loop, no blower, ~520 °C, 7 MPa, 500 kW, 220 kW DHR HX He/water
  - Commissioned in late 2016, scoping tests before 09/2017
  - Continuation in March 2018

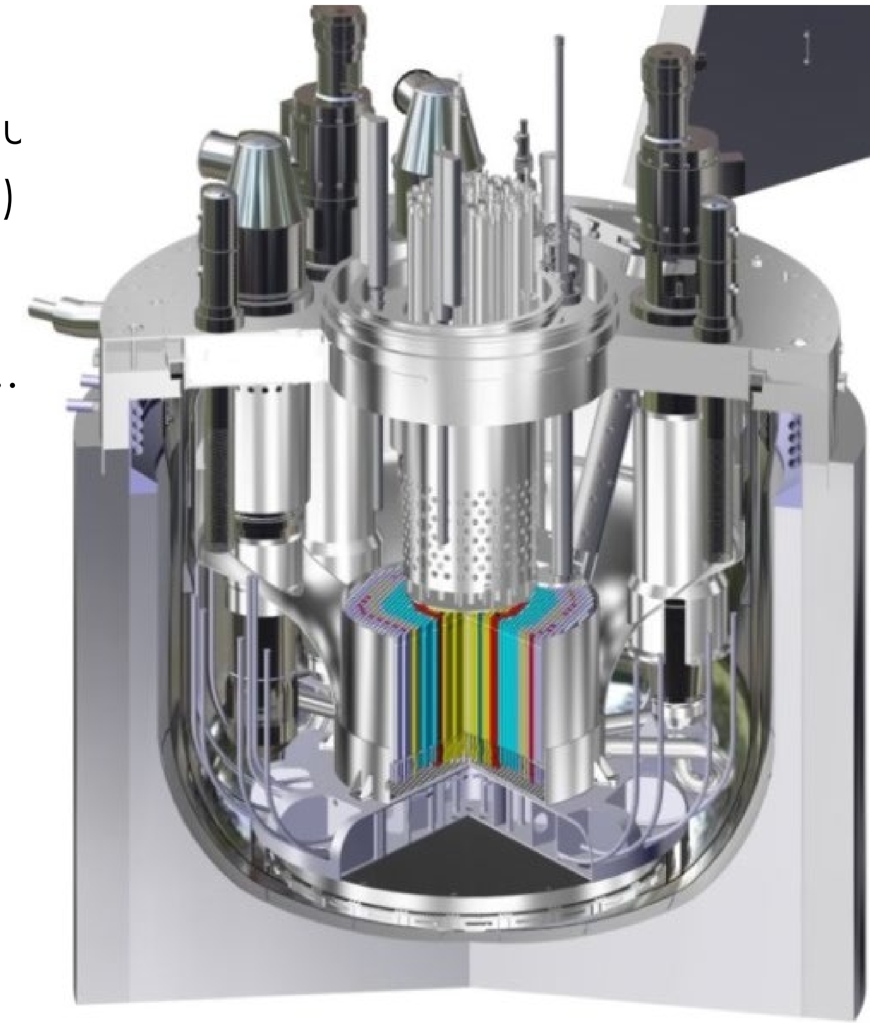
- **S-ALLEGRO (Pilsen, CZ): DHR-related issues**
  - Max. ~850 °C, 7 MPa, 1000 kW, 0.5 kg/s
  - **Phase I** (SUSEN): **1** main loop (blower), He/He MHX
    1 DHR loop (blower), He/water DHR HX
    Commissioned summer 2017, Scoping tests late 2018
  - **Phase II** (?????): **2** main loops (blower), He/He MHX
    3 DHR loops (2 HP + 1 LP blowers), He/water DHR HX

Primary system Main design options

- **100 MW_{th} pool-type reactor system confirmed as first option**
  - Innovative Primary Heat Exchanger (PHX)
  - Additional joint in the In-Vessel Fuel Handling Machine (IVFHM)
  - Design of the Primary Pump
  - Design and safety analysis of the Diaphragm

ASTRID main technical choices (basic design phase)

- 1500 MWth - 600 MWe pool type reactor
- With an intermediate sodium circu
- CFV core (low sodium void worth)
- Oxide fuel UO_2-PuO_2
- Preliminary strategy for severe accidents (internal core catcher..
- Diversified decay heat removal systems
- Fuel handling in Sodium, external storage
- Conical "redan" inner vessel adopted
- Reference lay-out (end of conceptual design phase):
  - ✓ *3 primary pumps*
  - ✓ *4 intermediate heat exchangers*
  - ✓ *4 secondary circuits*
  - ✓ *4 decay heat removal circuits*



Basic design phase 2016-2019

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MYRRHA phased implementation scenario

The goal of the MYRRHA project is the full realisation of the MYRRHA ADS facility

MYRRHA built in 3 phases

- Phase 1: LINAC injector + accelerator up to 100 MeV + associated experimental stations. Stage-gate decision (2024)
- Phase 2: Upgrade LINAC up to 600 MeV
- Phase 3: Construction of suitable reactor including spallation target module
- Stage 1 (2016-2024) :
  - Mid-term objectives by 2024
  - Supported by the Belgian Government decision of September 2018 : Belgium allocated 558 M€ to the MYRRHA project for the period 2019 – 2038

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